TUTORIAL

Title

Unleashing the Power of Airborne Computing in UAV Systems

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Duration

FOUR-Hours

Structure

1. Introduction (30min)
    a. Market Dynamics and UAV Innovations
    b. Regulatory Landscape and Policy Implications
    c. Exploration of UAV Applications
    d. UAV Functionalities and the Imperative for Onboard Computing
    e. The Drive Towards UAV-based Airborne Computing
    f. NSF Supports and Project Timeline
2. Deep Dive into UAV Applications (60min)
    a. Categorizing UAV Applications
    b. Layered Framework for Analysis and Design
        i. Mission Layer
        ii. Task Layer
        iii. Function Layer
    c. The Role of Computing in UAV Functions
        i. Control
        ii. Communication
        iii. Networking

   iv. Computing
d. Spotlight on Computing-Driven UAV Applications
   i. Precision Agriculture through UAVs
   ii. UAVs in Emergency Response

3. Crafting the Future: Design Guidelines and Platforms (90min)
   a. System Overview
   b. Key Components
      i. Quadcopter Unit
      ii. Control Mechanisms
      iii. Communication Infrastructure
      iv. Computing Core
   c. Prototype Insights
      i. Processor Selection and Carrier Board Design
      ii. Directional Antenna System Architecture
   d. Advanced UAV Functions Enhanced by Computing
      i. Reinforcement Learning for Antenna Orientation
      ii. Real-time Object Detection with Deep Learning
      iii. Advanced Coded Distributed Computing
      iv. Coded Federated Learning
      v. Software-defined radio-powered cellular base station
4. Concluding Remarks and Interactive Discussions (60min)
   a. Recap and Reflections
   b. Future Horizons and Open Challenges
      i. Integration of UAVs in 5G/6G Non-Terrestrial Networks
      ii. Facilitating UAV-based edge computing
      iii. Fully integrating Artificial Intelligence in UAV-based airborne computing
   c. Gathering Feedback for Continuous Improvement

Outline

Unmanned Aerial Vehicles (UAVs) have emerged as a transformative force in technology, capturing the attention of industries, government agencies, and academia. Supported by the National Science Foundation (NSF), our research initially spanned from 2017 to 2022 under a major NSF project and has now entered its second phase with a new award starting in 2023. Despite advancements in UAV control, communication, networking, and computing, fully unlocking the potential of airborne computing remains a significant challenge. This tutorial addresses this gap, laying the foundation for a new era of UAV-centric airborne computing.

This tutorial will: (1) explore current and emerging UAV applications, analyzing their complexities; (2) present real-world case studies demonstrating how airborne computing transforms UAV functionalities; (3) provide essential design strategies for next-generation UAV systems enhanced by airborne computing; (4) showcase our cutting-edge UAV-based airborne computing platform and latest prototype; and (5) explore pioneering UAV functions, encompassing reinforcement-learning guided antenna positioning, coding-driven distributed computing and federated learning, software-defined radio-powered cellular base stations, and deep-learning-enhanced object detection.

Aligned with IEEE SMC 2025's theme, this tutorial highlights the pivotal role of airborne computing in advancing UAV design and enabling innovative applications. Attendees will leave with a deeper understanding of the challenges, innovations, and future opportunities in UAV-based airborne computing.